

# THE GHARIAL (*GAVIALIS GANGETICUS*): A REVIEW<sup>1</sup>

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(With six plates and a text-figure)

Gharial were observed over a period of several years at wild locations and in captivity. Surveys were carried out to study the distribution, status and habitat of the species. The literature on gharial was researched. Gharial are fish eaters, being specialized by head morphology and riverine habitat. Other than fish, frogs were taken by captive animals. Birds and rats were usually refused, though the literature includes mammals and birds, as well as reptiles in the gharial's diet. Basking and swimming are common behaviours. One of the most thoroughly aquatic crocodilians, the adult gharial has weak front legs and does not 'high walk' or stand; locomotion on land is the 'forward slide'.

Adult males with prominent 'gharas' (narial excrescence) are dominant in an apparent social hierarchy with females and immature males. Adults are tolerant of immature animals and are sociable, often basking in groups. Interaction with mugger (*Crocodylus palustris*) was observed.

In India gharial nest in March and April, the dry season; the female lays 20-95 eggs in a hole 50-60 cm deep, dug with the hind feet in a riverside sand or silt bank, one to five metres from the waterline. Courtship was observed in captivity. Gharial rarely vocalize, the most common sound being a low growl when intimidated.

Egg collection, the rearing of some 2000 juveniles and the release of three and four year old in three newly gazetted sanctuaries, were carried out by the GOI/UNDP/FAO project. Captive breeding was successful in India at Nandankanan Zoological Park and is being attempted at the Madras Crocodile Bank Trust.

## INTRODUCTION

The gharial or gavial has remained one of the least known crocodilians despite its former commonness, wide distribution, size and accessibility. It was first described by Gmelin (1788). Adams (1867) expounded on the abundance and gregarious nature of *Gavialis* in north India. Francis (1910), Lowis (1915) and Rao (1933) remarked on their abund-

ance on the Indus River, Pakistan. I.A.K. (1921) recorded "plenty" of gharial in the Gandak River, Nepal and Shortt (1921) recorded that parts of the Kosi River in Bihar were "teeming" with them.

Anderson (1875) gave the first description of a nest, eggs and young. Hornaday (1885) described the gharial's basking habits, vocalization and the 'ghara' or narial excrescence and proposed early April as the laying period.

Several notes appeared, mainly in this *Journal* in the first 65 years of this century mentioning gastroliths, unusual stomach contents and exceptionally large specimens. Biswas (1970) reported its extremely depleted status

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in some areas; Whitaker *et al.* (1974, 1976) and Bustard (1974) gave further evidence of its rarity.

*Gavialis gangeticus* is the sole surviving member of a once well-represented family (see Fossil history). It is both taxonomically as well as structurally unique, having the most attenuated snout of all crocodylians.

It is light to dark olive dorsally, with dark cross bands (more prominent in young animals) and a white or yellowish underside. The snout is 3.3 to 5.5 (in young) times the basal width; the individually socketed long thin teeth are arranged thus: 5+23—24. Scales are

25—26

arranged in uniform longitudinal rows with a pair of post-occipitals and nuchals consisting of four transverse rows of 2 scales, continuous with the dorsal scales. There are 21-22 transverse rows of dorsals (6 scales wide), 18-20 double crested caudal scales, 21-24 single crested caudal scales and 30-31 transverse rows of ventrals (Wermuth 1953, Braziatis 1973, Singh & Bustard 1976).

The future of the gharial appears to be secure with the formation of several protected habitats and the successes of State rehabilitation projects in India. Four research scholars have been studying the species for the past several years.

#### MATERIALS AND METHODS

We have been involved in the survey, study and captive rearing of gharial in India for several years. Most major habitats in India, Nepal and Bhutan were surveyed using both day and night censuses, behavioural observations on wild and captive groups were made, and young (from wild collected eggs) and wild caught adults were reared since 1973. At the

Madras Crocodile Bank (MCB) two adults and four juveniles are being reared in a large, landscaped enclosure for captive breeding. Basu carried out egg collection annually for six years in Uttar Pradesh (Girwa River) and Rajasthan (Chambal River).

The literature on gharial was surveyed and is reviewed here to provide a current, but yet incomplete, summary of the species' biology.

#### RESULTS AND DISCUSSION

**Fossil history:** Members of the family Gavialidae have been found in Tertiary deposits in Asia, North and South America and Europe. Five Pliocene species were found in the Siwalik and Narmada Hills in India, one almost indistinguishable from *Gavialis gangeticus* (Smith, 1935). Hecht (1972) discussed the differences between the Oligocene, Pliocene and Miocene gharial of Colombia, Venezuela and Florida and the tomistomine crocodylians.

**Distribution and status in the wild:** The range of the gharial includes the river systems of the Indus (in present day Pakistan), the Ganges (India, Bangladesh, with tributaries in Nepal), the Brahmaputra (with one tributary, the Manas River, in Bhutan) and the Mahanandi in Orissa. The single record for the Maingtha stream of the Irrawadi in Burma (Barton 1927) has not been supported by further specimens. Aung Moe (pers. comm.) reiterates the unlikelihood of this species occurring in Burma. Bustard and Choudhury (in litt.) report that the gharial may have occurred on the upper reaches of the Godavari River in recent times.

Old references indicate the gharial's abundance in the past: Indus River in Pakistan (Francis 1910, Rao 1933); Gandak River in Nepal (I.A.K. 1921); Jumna River in Uttar Pradesh (Hornaday 1885), Kosi River in

Bihar (Shortt 1921). Several authors mention seeing groups basking together and in one area on the Jumna River, 22 were counted in two hours (Hornaday 1885).

**Population size and status:** Due to the combined effects of shooting, nesting, hooking for skin and meat and loss of habitat from river alteration and human settlement, the gharial dwindled to a trace of its former abundance by the end of the 1960's (Biswas 1970, Whitaker *et al.* 1974). By the mid 1970's the largest known wild concentration was 34 animals including adults and juveniles in 5-6 kms of river at Katerniaghata, Uttar Pradesh. Two other relatively substantial breeding populations were located on: a) the Chambal River (Rajasthan, Madhya Pradesh and Uttar Pradesh) consisting of perhaps 50 adults and 100 smaller animals in 600 kms of river; b) the Rapti-Narayani Rivers in Chitawan National Park, Nepal, where 14 adults were recorded (B. Wright, pers. comm.).

Gharial seem to be nearly extinct in Bangladesh (R. Khan 1979), Bhutan (Bustard 1979) and nearly so in Pakistan (Minton, pers. comm.). The total wild populations was estimated as being under 200 (Whitaker & Daniel 1978). As a result of captive rearing and release there are currently about 500 gharial in India now, in the wild. Another 1800 are in captivity.

**Habitat:** Annandale (1912 in Biswas, 1970) remarks that its distribution corresponds to that of *Trionyx gangeticus* and *Platanista gangeticus*, and literature emphasizes its preference for deep fast flowing rivers. It has even been surmised that one of the reasons for the lack of success in captive breeding has been the failure to provide flowing water for the potential breeders. However, adult gharial are not totally restricted to mainstreams; they have been observed in still water branches of rivers and an adult was even seen in a jheel (lake)

surrounded by sand hills ("Sind" 1922). Rao (1933) writes of a sudden increase in gharial on the upper Indus and reports seeing them in open water in the jungle as well as on the main river and tributaries. However, these seem to be exceptions and the prime habitat of the gharial is deep rivers. These include the northern tributaries of the Ganges (up to 300 m above MSL) which drain from the glaciers and melting snow of the Himalayas such as the Girwa, Gandak and Kosi; the rain fed tributaries such as the Chambal, Ken and Son; the Brahmaputra with tributaries both from the Himalayas (north) as well as the smaller hill ranges (south); and finally the Mahanadi in Orissa, far south of the rest of the gharial's range.

Adult gharial show a preference for the comparatively velocity free state found in the deep "kunds" or holes at river bends and confluences. Smaller animals seem to conserve energy by resting out of the main stream in sheltered backwaters, particularly during the monsoon (July-September) when water velocities may multiply by a factor of 5.

For most of the year the Ramganga River in Corbett National Park cannot be called a deep, fast flowing river; gharial are concentrated at the deep pools at sharp bends and this distribution may be characteristic of past habitat preference. The occurrence of gharial in some of these larger hill streams, though perhaps not prime habitat, indicates how little undisturbed area remains where the species can survive.

Although there is one report of nesting in a mud bank (Bustard 1980), gharial usually use the steeper sand banks for nesting. Sand and rock outcrops are preferred basking sites and deep water at river bends and junctions a usual feature of confirmed gharial habitat. The relationship and evolutionary significance

of habitat to the habit of depositing eggs in a hole (hole nesting) has been suggested in other crocodylians (Carr 1963, Greer 1970). Bustard (1974) notes that while habitat loss is a serious threat to the gharial's existence, gharial have adapted to some degree; nesting in nullahs (side creeks of main rivers) is the main adaptation.

In contrast to the adult and subadult habitats, young during the first year seem to favour hiding in vegetation or debris, often roots or fallen tree branches in the water (Singh 1976). In mid August, 1978, a 57 cm gharial was caught by a farmer in a water logged lowland (Srivastava 1978). It is suggested that in the past when gharial were numerous the young often frequented shallow water and densely vegetated flooded areas away from the main rivers.

**Size:** Hornaday (1885) judged large gharial he observed to be over 5.40 m long and mentions a stuffed specimen at Allahabad Museum of 5.10 m and another at Jardin des Plantes, Paris, of 6.18 m. Pitman (1925) gives 6.45 m as the maximum length, Bustard (1974) estimates that gharial reach over 8 m and that 6-7 m animals were once common. Two adult males at Satkosia Gorge in Orissa are estimated by Bustard (in litt.) to be 6.6 m long. Shortt (1921) felt that 4.20 m is the upper limit for females and well over 5.70 m for males. Anderson (1875) gives the length of gharial hatchlings as 395 mm. Recently average lengths have varied from 325-374 mm and average weights have ranged from 75-97 gm (Biswas 1970, Singh 1976, 1979). The wild juvenile captured near Katarniaghat, Uttar Pradesh and considered to be a yearling, was 75 cm in length and weighed 550 gm (Srivastava 1978); however, its age was not known. Average lengths and weights of hatchlings from 6 nests are given in Table 1. Ave-

rage hatchling sizes of Girwa River (Uttar Pradesh) gharial have been found to be significantly smaller than those from the Chambal River (Rajasthan) population.

**Growth rates:** A UNDP news release of late 1977 states that the 1409 juvenile gharial being reared in state projects reach an average length of 1.02 m in 18 months. Singh (1979) reports they reach 1 m in 12-18 months. A 2.7 m male gharial at the Madras Crocodile Bank was 18 years old, and a female of 2.4 m estimated to be over 20 years old (Whitaker *et al.* 1979). Choudhury (1979) gives the following average growth rates for gharial released in Uttar Pradesh in 1979.

No.	Age	Total length	Weight
5	3 yrs, 9 mo.	193 cm	22.5 kg
9	2 yrs, 9 mo.	140 cm	5.28 kg
15	2 yrs, 9 mo.	167 cm	13.6 kg

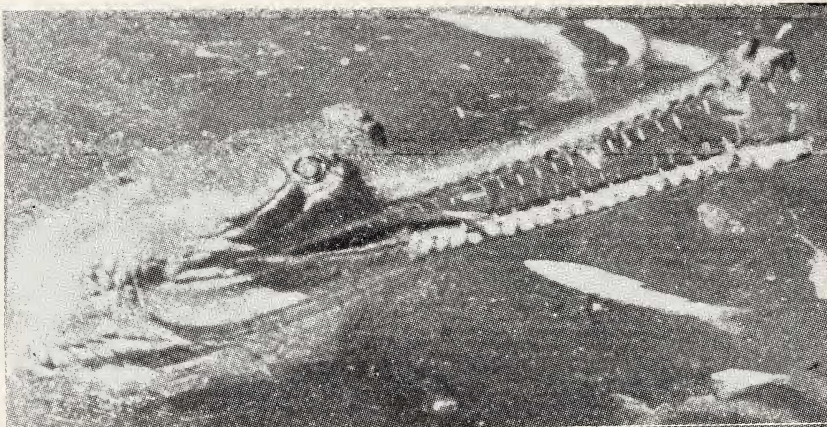
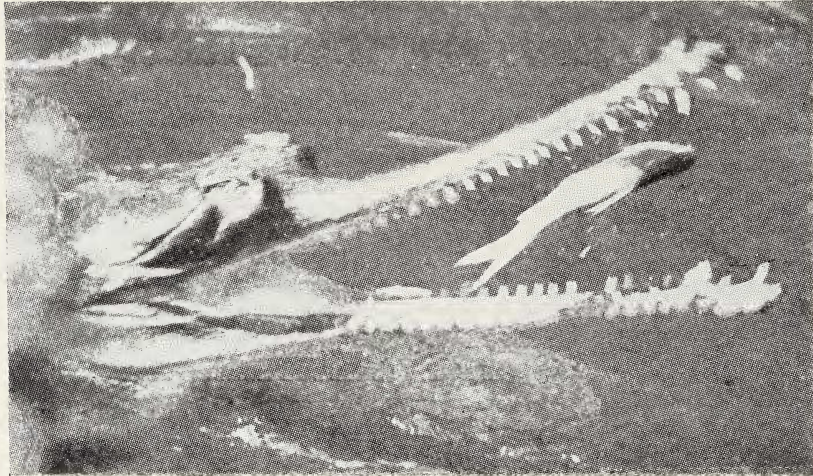
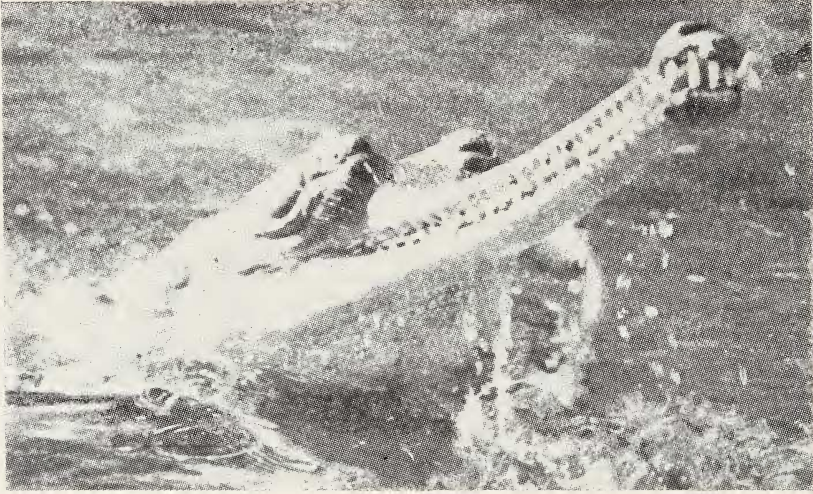
Biswas (1977) gives growth figures for a captive reared male gharial at Nandankanan Biological Park, Orissa. At 1 year, 8 months and length was 135 cm; at 11 years, 6 months the length was 250 cm and at 15 years, 7 months the length was 270 cm. Table 2 gives the average measurements of 588 juvenile from 6 months to 5 years of age.

**Longevity:** The only longevity record in the literature is from a female at the London Zoo which died in 1972, at the age of about 29 years; its total length was 3.43 m (Guggisberg 1972, Martin and Bellairs 1977). Fishermen who live in the past geographic range of the gharial commonly stated the 'age of man' and 'over 100 years' as being the age attained by a gharial. Certainly their late maturity and large size suggest a long life span.

**Sexual maturity:** In cloacal probing of 20 gharial from 1 to 3 m, Whitaker *et al.* (1979) point out the difficulties of sex differentiation in animals under 2 m in length. A 2.7 m male,



Adult male gharial with prominent ghara.  
(Photo: *Rajesh Bedi*)



This sequence illustrates a gharial positioning a fish by tossing and then swallowing it.  
(Photo: *Rajesh Bedi*)

18 years of age had a penis only a few cm. long. Clitoral and penal tips appear identical in sub-adults. We feel that the rate of sexual development is considerably slower than in other crocodylians.

Hornaday (1885) records that the smallest female he shot which contained developing eggs (15) was 2.70 m. A 2.97 m female shot on the Sutlej River contained 56 eggs (Parshad 1914). From these data, the minimum breeding size of a female gharial would appear to be approximately 2.6 m. Males appear to usually reach maturity at a length of over 3 m and an age of 13 to 14 years (Biswas 1977).

Geoffrey-Saint-Hilaire (1925) stated that the narial excrescence or 'ghara' of the gharial is a development peculiar to adult males. It is generally considered to be a sex character of very large animals. Hornaday (1885) found no trace of a ghara in 26 specimens up to 3.6 m in length; the only ones he saw were on 'monsters' of 5-6 m. Large males with gharas are traditionally recognized as the adult males and are given special names (see Table 3) (Whitaker *et al.* 1974; Singh in Martin and Bellairs 1977). Biswas (1977) outlines the development of the ghara of a captive male. It first appeared at an age of 11 years 6 months and at 2.7 m (15 years 7 months) the male had a well developed ghara with the following measurements: length — 5 cm; anterior width — 4 cm; posterior width — 6 cm; height — 3.5 cm. Bustard (in Bellairs 1977 and pers. comm.) sexed this male by cloacal probing and confirmed that it appeared to be mature.

Hornaday (1885) thought the ghara was composed of bone and Neill (1971) discredits its existence. Biswas *et al.* (1977) note that the ghara grows over the nostrils and that the hissing of the surfacing male is caused by this blockage. Earlier, Champion (1934) notes

that gharial hiss 'like escaping steam'. The whistle-like exhalation was clearly heard at a distance of 75 m across the Chambal River.

Martin and Bellairs (1977), in their timely treatment of the unique but little known characteristic, give an account of its morphology. They propose three possible functions of the hollow, cartilagenous ghara: as a resonator, as a visual sex recognition character, or in bubbling, spouting or other sexual behaviour. Records of vocalization in gharial are scanty (see 'vocalization'); furthermore there are very few adult males either in captivity or observable in the wild. The function of the ghara must be of important enough evolutionary significance to remain a trait of the species for so long and to offset its disadvantage in creating friction while snapping at fish.

The 3.43 m female at the London Zoo has a partially developed ghara about 3 cm high and 5.4 cm across the base; Martin and Bellairs suggest the animal was abnormal.

#### HABITS

*Prey capture and food:* The strongly attenuated snout and rows of uniform sharp teeth are reminiscent of other well known fish eating taxa such as the bottlenose dolphin (*Tursiops* sp.), gangetic dolphin (*Platanista gangeticus*), garfish (*Lepisosteus* sp.) and needlefish (Belontiidae). The thin snout meets considerably less resistance when snapping at fish underwater than does that of a mugger for example. Supported by a relatively long, well muscled neck it is a most efficient fish catcher.

Bustard (in Bellairs 1977) says that the gharial is probably the most predominantly fish eating of all extant crocodylians. Singh (1977) points out the distinctive adaptation of the snout and teeth to fish eating. He describes and illustrates the method used by juvenile

gharial to manoeuvre fish back to the opening of the gullet by jerking the head back to the side; the fish usually slides in head first. The greater weight of the fish's head allows for this, the most efficient position for swallowing. Singh also describes the habit of small gharial which may run out of the water with fish, particularly large active fish which are likely to escape. Gharial also tear their prey apart by the head jerk technique used by other crocodylians. Whitaker (1975) gives a series of photographs showing the typical swallowing procedure. Neill (1971) describes feeding in juvenile gharial. The sideways snap at fish involves the head and neck only.

Singh (1976) remarks that juvenile gharial feeding on tadpoles and fish seem to rely more on tactile reception than on sight for catching prey. This is certainly the case with a gharial born blind at Satkoshia Gorge (Singh, pers. comm.). An adult female at MCB which is blind in one eye will catch thrown fish with equal success on both sides. The 2.8 m male gharial at Nandankanan watched an attendant throw a live 1-2 kg murrel fish, submerged and had the fish at the surface of the almost opaque water within a few minutes. One specimen caught a peacock which flew into its pen but did not swallow it (Acharjyo, pers. comm.) Juvenile and adult gharial at MCB has been observed feeding on frogs and catching free living *Tilapia* in their large pond. Rats thrown to them were often snapped at, occasionally 'chewed' and held for some time but never swallowed. While captive juvenile and sub-adult gharial are fairly heavy feeders, larger captive specimens subsist on proportionately less feed.

S. Choudhury (in litt.) estimated that captive reared juvenile gharial consumed between 1 and 5% of their body weight in fish daily

and that the rate of consumption was temperature related.

*Stomach contents:* The larger the gharial grows the shorter and heavier set is the snout in relation to its body length (Martin and Bellairs 1977). Large gharial over 15 ft have fairly massive, strong jaws and a large gullet; one can easily imagine their dealing with large strong prey or large items of carrion. Shortt (1921) records that gharial feed on turtles in addition to fish; Biswas (1970) records *Trionyx gangeticus*, the gangetic softshell turtle, as a gharial prey item. Forsyth (1910) records bird remains and weeds in the stomach of a 4.8 m male gharial on the Sarda River. "Sind" (1921) reports that a gharial caught a wild cat (*Felis chaus*). Pitman (1925) reports but doubts a correspondent's claim of finding the hindquarters of a donkey in the stomach of a 6.45 m gharial on the Ghara River.

Hornaday (1885) gives the stomach contents of one 3.3 m female as 3 half digested fish; another 3 m female killed the same day contained only a few bits of a clay pot; others contained only fish remains. It must be kept in mind that fish are soft bodied and quickly digested. Contrary to the standard conception of crocodylians as voracious reptiles with great appetites, Cott (1961) and others have reported and remarked upon the high percentage of empty stomachs encountered in large samples of Nile crocodiles.

Hornaday (1885) unequivocally states that gharial cannot be man-eaters judging from the way his men plunged into the river knowing they were there. A fisherman interviewed on the Brahmaputra in Assam alleged that "many years ago" a seven year old boy was caught and drowned by a large male gharial as the boy was hunting prawns in the shallows. Dodsworth (1910) apparently examined a large number of gharial stomachs and remark-



ed on the number of gastroliths found. Large specimens had empty stomachs except for stones. Shortt (1921) and Biswas (1970) report that ornaments are sometimes found in gharial stomachs. Smith (1931) notes that they will feed on corpses, the probable source of the ornaments. Martin and Bellairs (1977) record human leg bones taken from the stomach of a 4.83 m specimen killed in 1897. Neill (1971) suggests that ornaments might be picked up by gharial on the river bottom as gastroliths. It is true that hard objects other than stones are picked up and swallowed by crocodilians. Forsyth (1910) records finding 4.5 kg of stones in the stomach of a 4.8 m male, the three largest about 225 gms each. He raises the question of whether the stones aid digestion. In 1921 Shortt wrote, "there is always a collection of stones, sometimes quite large, to aid digestion I suppose." Gastroliths remain a subject of considerable debate in spite of Cott's hypothesis on the hydrostatic function of gastroliths (in Nile crocodiles).

#### Predation:

Basu (1980) reports rats tunnelling into two of the 13 nests located on the Chambal in 1979, resulting in loss of 50% of the eggs. The loss of 33 eggs to rats represents about 7% of the total of almost 500 eggs collected from the 13 nests. Between 1976 and 1980 nine attempts of nest robbing by jackals were recorded at the Chambal River of which seven were unsuccessful, for a predation rate of 5.9% for the 34 nests observed (Basu, unpub. obs.).

Female gharial chased away jackals on three occasions, once after about 14 eggs had been eaten. Several predators on other crocodilians found in gharial habitat are potential predators on the eggs and young. These include wild pig, jackals, common, desert and yellow moni-

tor lizards, domestic dogs, large wading birds and birds of prey. Cannibalism has not been noted in gharial. Tolerance for young animals by adults is noted by Hornaday (1885) in the wild and in captivity at MCB and Mysore Zoo. Thirty eight young from a clutch of 46 were seen with an adult 40 days after hatching, indicating that maternal protection is an important deterrent to potential predators.

Moidart (1895) reports a turtle killing a small gharial in Rajputana, probably in the Chambal River. Indeed the genera *Trionyx* and *Chitra* are among the largest freshwater turtles in the world. These plus fish like *Bagarius* will no doubt prey on small gharial. The most consistently reported predator on large gharial is man. Most of the references on gharial in this *Journal* refer to the killing of one or many gharial. Aside from factors such as habitat loss, the almost total demise of the species has been due to hunting for skin and meat and human predation on the eggs for eating (Whitaker 1974, Bustard 1974).

#### Amphibious behaviour:

Basu and separately Dodwell in Whitaker *et al.* (1974) remark on the gharial's habit of returning to the same spot every day for basking, which makes them very vulnerable to predation. Singh and Bustard (1977) report that captive juvenile gharial at Satkoshia in Orissa bask for longer periods than do mugger. They typically bask for a few hours after sunrise and sometimes at other times of day. They basked daily in winter and very little in summer.

Whitaker *et al.* (1979) observed two gharial sporadically during April 1974 and report daily basking, mainly in the morning hours until noon. By 18th April increasing temperatures were apparently responsible for the

shift in trend from basking on the rocky shelves to basking on sand banks in the shallows. High temperatures and a sharp breeze seemed to discourage afternoon basking.

Hornaday (1885) was impressed by the amount of time during the day the gharial spent basking. He attributes this to the coldness and swiftness of water in their typical habitat. Shortt (1921) accurately outlined the basking pattern. In the cold season (Dec.-Feb.) gharial emerge after 9 a.m. and return to the water at 4 p.m. As the hot weather advances toward its peak in June, they come out earlier in the morning and then later in the evening, returning to the water between 10 a.m. and 5 p.m. He reports that very large animals occasionally bask at night during the hot weather.

#### **Gaping:**

As reported for most other crocodylians, gaping is a common habit of basking gharial. A discussion of its possible significance in thermoregulation is beyond the scope of this paper. Ross (unpublished, 1975) writing about the Corbett Park animals, suggests that the frequent display of the yellowish interior of the gharial's mouth while basking was actually a threat display directed at mugger basking nearby. Whitaker *et al.* (1979) report that typical gaping in gharial at Corbett was for 10-20 minute periods with head raised about 20°. At MCB gaping is a regular feature of basking at all times of the year. In summer months (at the peak of the hot season) juvenile and adult gharial would rarely leave the water during the day but hold their heads out of the water at 20-30° angles, gaping, while keeping the rest of the body submerged. This was generally observed in the evening about an hour before sunset and seems to support the

'cleaning hypothesis', i.e. that the crocodylian thus rids its mouth of algae and parasites:

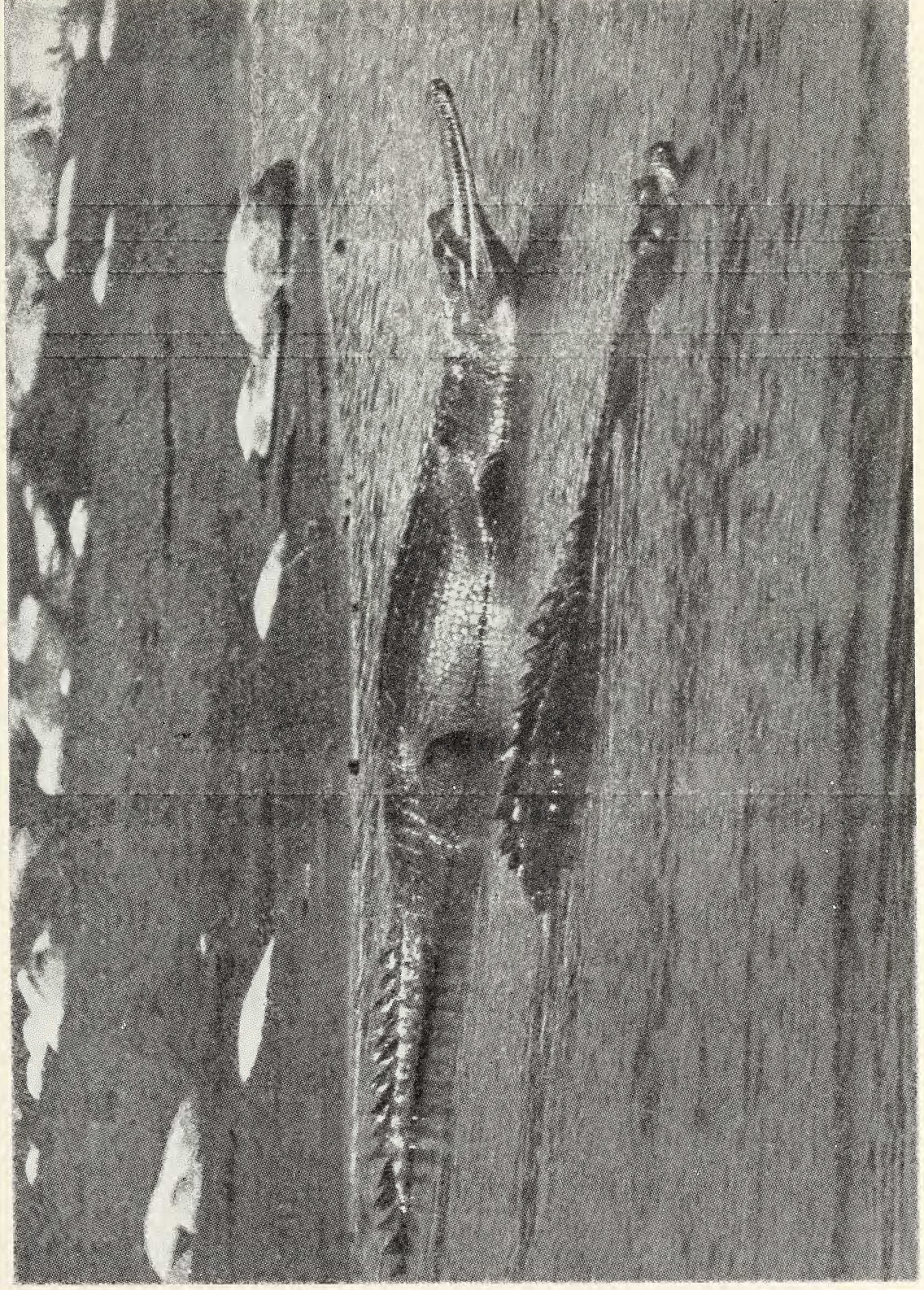
#### **Swimming:**

The heavily muscled tail, well webbed hind feet and elongated smooth body are all adaptations for an aquatic existence. Gharial swim with limbs folded against the body except when using them for stability and the 'back dive'. Whitaker *et al.* (1979) observed gharial 'walking' on the bottom of the clear Ramganga River and reported a sinuous bending of the body reminiscent of the varanid gait.

#### **Terrestrial locomotion:**

Hornaday (1885) was the first to describe the 'lazy' sliding gait of the gharial on land. Singh and Bustard (1976) report the three gaits described by Cott (1961) for Nile crocodiles (high walk, belly run, gallop) in gharial up to ten months of age. Bustard and Singh (1977) describe the gait of larger gharial as a 'forward slide', pushing with all four limbs in a gait the authors describe as similar to that of a green sea turtle on land. They point out that gharial rarely move far from the water's edge. When they haul out for basking they generally make a 'U' turn near the edge of the water. This locomotion (due to feebly developed front feet), the authors point out, greatly restricts terrestrial movement and could be a primitive mode derived from this oldest living family of crocodylians. The fact that gharial live in deep flowing rivers which do not dry up and that they only need to leave the water for basking and nesting favours the diminishment, or nondevelopment of more effective powers of terrestrial locomotion.

Whitaker (1978) described a 2.8 m captive male gharial at MCB which climbed over a 1 m brick wall and used the forward slide rather than a 'high walk' gait to travel a



Wild gharial on the Girwa River, Uttar Pradesh.  
(Photo: *Rajesh Bedi*)



Egg collection at a gharial nest site on the Chambal River, Rajasthan.  
(Photo: *Rajesh Bedi*)

nocturnal circuitous route of 650 m around the other enclosures before coming back to its own enclosure. Overland migration by gharial is not likely to occur but in case of necessity (accidental isolation in a dry area) short distances can be negotiated by smaller animals.

**Homing/migration/dispersal:**

Singh (1977) describes a 1.5 m gharial caught on the Mahanadi River and released 15 km downriver, which returned to its original place of capture. Singh (1976) mentioned the extreme sensitivity of hatchling gharial to a change in the arrangement of the *Salix* weeds in their ponds. Alterations in the weed arrangement caused them to leave the water.

Rao (1933) notes the northward migration of large numbers of gharial on the Indus River (Pakistan) and attributes their continued presence on the upper Indus to the closure of a (then) newly constructed barrage. He states that they generally go upstream with the rising water at monsoon time and downstream when the river goes down in the fall and winter. Biswas (1970) reports that gharial are said to move downriver from the Kosi in Bihar to the Ganges during flood time (monsoon). Gharial at Katarniaghat are observed to migrate locally (8-10 kms) every year, always orienting themselves upstream at the flood water period in the monsoon. Adult migration is always very local and seems to be merely to maintain the home range. Juvenile migration (dispersal) is predictably longer and one released specimen travelled over 150 km downstream in a few months (Basu, unpub. obs.).

The return of the female to the nest site as reported by Singh and Bustard (1977), Bustard (1980) and Basu (1980) demonstrates the homing instinct as does the often reported propensity of gharial to return to the same spot to bask.

Bustard (1974) estimates that the 34 young he observed with a large female were a month old, indicating that young stay with the female for at least a month. Maternal attendance may last for at least a year as it does in the mugger (Whitaker, unpub. obs.). It is likely that in undisturbed conditions gharial display protective behaviour for several months or longer. Bustard (1979) and Choudhury (1979) give data on dispersal of captive reared gharial. Table 4 gives the average dispersal distances for animals released in April, 1979.

SOCIAL ORGANIZATION AND REPRODUCTION

**Interaction with mugger:**

Several of the older references refer to groups of mugger and gharial living in close proximity. Champion (1934) writes that he could count up to 45 of both species in a day on the Mohan River in Uttar Pradesh. He records watching a 3 m gharial chase a similar size mugger from a favoured basking spot. This is contrary to the observations by us and of others who have observed mugger as the dominant aggressors. Whitaker *et al.* (1979) observed interspecific aggression at the Gharial crocodile pool in Corbett National Park. One mugger nested on the same midriver island in the Chambal River as 3 to 5 gharial during 1976-1980. The mugger nest site was separated from the others by its rocky aspect (Basu, unpub. obs.).

**Territoriality/Sociality:**

In general it was observed that interspecific aggression is analogous to intraspecific territorialism, with size being the most important determinant of dominance. The impression gained in interviewing persons familiar with the species when it was abundant is that the 'harem' group consisted of a large 'knobbed'

male with several females. There are numerous references to the gharial's preference for the same basking spot but nothing is known of the degree to which territoriality manifests itself. Basu (1980) writes of a sand bar and nearby rocks which were the regular basking places of 4 adult males (though never together) and 6 females. At Mysore Zoo a 1 m juvenile was often seen basking on the back of one of the 3 m to 3.5 m adults. At MCB adults and juveniles have been housed together for several years with almost no agonistic interaction. At Nandankanan Zoo, Orissa a newly introduced adult male killed the smaller resident male in the breeding enclosure, indicating a territoriality similar to that seen in other adult male crocodylians.

#### **Vocalization:**

Champion (1934) writes that a 3 m gharial 'bellowed hard' a number of times, apparently to intimidate a mugger which had usurped its basking spot. Although vocalization has never been reported in association with breeding, gharial certainly have the capacity for making sound in distress situations. Hornaday (1885) wrote that a 3 m animal which had been shot 'groaned three or four times like a strong man in distress'. This groaning sound has been heard several times at MCB from animals of 1.5 m to 2.7 m when closely approached. It often preceded a sudden rush for the water. Choruses of groans were heard in groups of juveniles at the Kukrail Gharial Rehabilitation Centre. Hornaday goes on to say that wounded gharial would often 'bawl aloud like calves when seized', a sound evidently similar to the distress cry of a large mugger when caught. One of his shot animals (3.45 m female) 'bawled' more than a dozen times while struggling. Similarly Basu (1974) reports that fishermen say that when caught on hooks buried at

basking sites gharial emit loud roars. Rajesh Bedi (in Basu 1980) heard the 'noisy grunt' of a gharial at night as it approached what was presumably its nest.

#### **Courtship and mating:**

Mating is in December-January, winter months with low water levels and low temperatures. The near adult male gharial at MCB was observed to jaw slap on two occasions at breeding time. On both occasions the behaviour consisted of three open mouthed slaps on the water surface in quick succession. Compared to the powerful signal in some crocodiles and the American alligator, the gharial's jaw slap is feeble. The jaw slap was followed by a hissing exhalation from the nostrils. One occasion the sun was behind the animal and a cloud of droplets rose to about a meter over its head while hissing. According to Martin and Bellairs (1977), the ghara on the male's snout (Fig. 1) may be an important component of breeding, functioning as a vocal resonator. Considering the weakness of the jaw slap, it certainly seems that vocalization would be the more effective signal. No response by conspecifics was observed.

At Nandankanan Biological Park courtship behaviour has been observed for several successive seasons. Maharana (pers. comm.) observed courtship in January and February and infers that the male uses the ghara as a hook on the female's snout for leverage when mounting. A photograph by R. Bedi (in Gore 1978) shows a male and female with crossed snouts, a feature of courtship behaviour also observed at MCB. The following is a description of one sequence. On 20 December 1977 at 1630 the 2.7 m male (without ghara) was observed to be on top of the female at the deepest end of the pond. The pair submerged briefly, surfaced and separated. At 1640 the

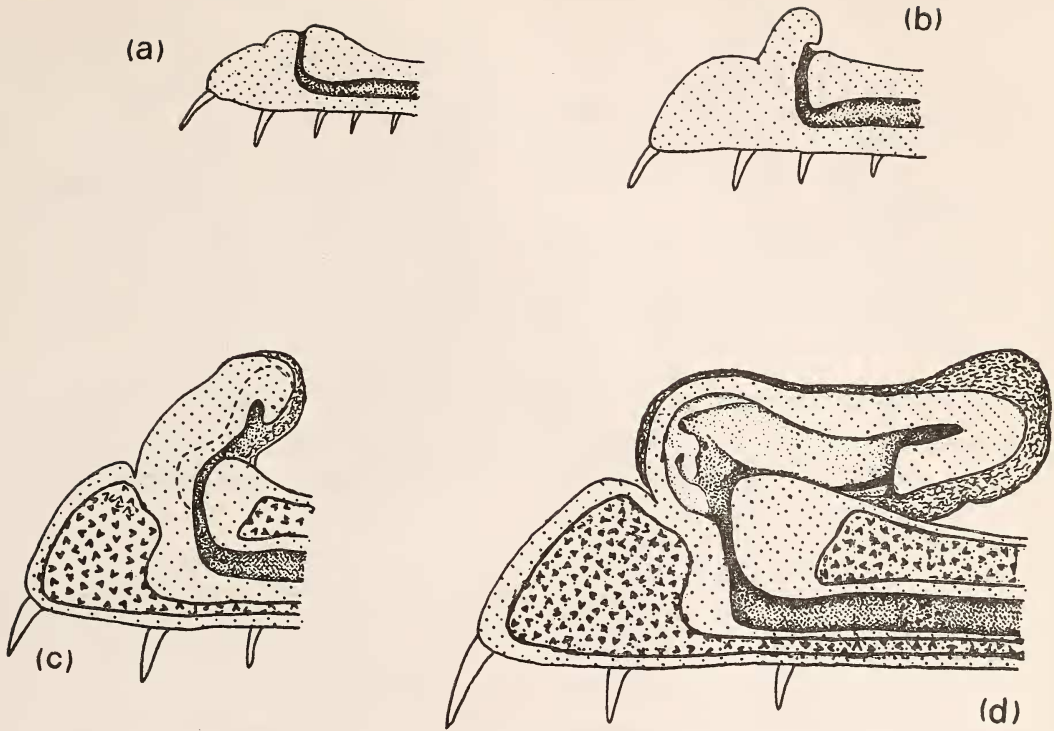


Fig. 1. Development of the ghara or narial excrescence of the male gharial (after Martin and Bellairs, 1977). (a) juvenile, (b) subadult, (c) subadult, (d) adult.

male approached the female. The female snapped at the male several times, bubbling and geysering small spouts of water from her nostrils. The male then crossed snouts with the female and swam behind her, he mounted and the pair submerged. A few minutes later the female surfaced among the weeds at the shallow end of the pond. The male approached her and when close, the female raised her head exposing the white underside of her throat. The male turned and swam away. Shortly thereafter the female swam toward a 2 year old, 1.25 m subadult and chased it out of the water. This was one of the few occasions in which aggression toward smaller animals was seen.

**Nesting:**

Nesting is strongly seasonal, occurring in March and April, during the period of high ambient temperatures and between the cold winter months (0-4°C) and the monsoon floods. Sites with fine sand are chosen in preference to banks of coarse sand. On the Chambal River the earliest nesting was recorded on 7th April. Anderson (1975) gives the first description of a gharial nest: 40 eggs buried in sand. The nest was in two layers of 20 with sand between. It is possible the female was disturbed during laying, resulting in the two tiers. The layer configuration of three nests on the Chambal was as follows:

Layer	Nest 1	Nest 2	Nest 3
1	20	20	13
2	20	20	23
3	4	7	—

It is presumed that the layers form by the action of gravity rather than by a deliberate effort of the female.

Gharial invariably dig their pitcher-shaped nest holes at night on steep sandy river banks. Singh and Bustard (1977) report the use of mud banks for nesting on the Chambal River after loss of sand banks from damming. The average nest hole is 40 cm deep and the spoor formation at trial nests confirms that the hind legs are used in digging, though Bustard (in litt.) saw a female engaged in apparent nest hole digging with her fore-limbs. Nests are located 1 to 5 m above the water level and up to 10 m away from the water's edge (Singh and Bustard 1977). The spoor of nesting females was found at a maximum distance of 22 m away from the river.

It is possible that gharial are communal nesters, as reported for the Nile crocodile (Cott 1961). Basu (1980) reports three nests on one 30 m sand bar on the Chambal and close proximity of nests at other sites. Trial nest holes are a common feature of gharial nesting. 5 females on the Karnali River (Nepal) made 12 trial holes without nesting. The digging of these trials is a manifestation of the nesting urge of the female (Bustard, in litt.). The depths of trial nest holes are compared below with actual nest holes.

Trial holes	Number	Range of depth	× depth
	23	27—52 cm	35.04 cm
Actual nest holes	22	20—54.5 cm	40.11 cm

Prior to the actual deposition of eggs gharial exhibit nesting behaviour consisting of

movement to the vicinity of nest site, travel over the nest site and the digging of trial nests. In the Girwa river 4 females that had been basking on mid-river sand bars since mid February 1975, gave up the security of these basking sites and appeared below nesting sites on the right river bank on the morning of 31st March. One nest was located on 22nd April in which eggs were deposited on the previous night but nesting activity continued till the night of 29 April. Although trial digging was first noticed on the night of 15 April, the duration of the nesting period is computed to be 29 nights, that is, the date of first appearance below the nest sites to the post laying cessation of activity.

TABLE 1  
HATCHLING MEASUREMENTS

Nest No.	N	Weight in grams		Length in cms	
		Range	Average	Range	Average
1	50	96-126	116	35-38.5	35.7
2	38	82-99	90	34.5-36.5	35.5
3	4	121-125	123	38-39	38.4
4	25	84-107	94	35-39	37.4
5	49	95-123	115	34-37.5	35.7
6	32	103-130	118	36-39.2	37.7

TABLE 2  
GROWTH RATES

Year of Hatching	Age Class (year)	Number	Weight (Kg.) Range X	Length (cm) Range X
1976	4-5	6	27.5-36.0:31.8	209-218:212
1977	3-4	143	5.5-28.0:12.7	130-209:172
1978	2-3	196	1.0-11.0: 6.8	80-158:138
1979	1-2	91	0.35-4.5: 1.8	61-116: 88
1980	0-1	152	0.14-0.4: 0.6	42-66 : 56

On the Chambal River the spoor of an adult gharial (presumably a female) on 22 March indicated that the animal had travelled



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TABLE 3  
VERNACULAR NAMES OF GHARIAL

Language	Place	Vernacular name(s)
Urdu	Pakistan	Sansar
Hindustani	North India	Gharial (ghara=mud pot), nakaar
Bihari Hindi	Bihar	Nakaar, Basoolia nakaar (male)
Oriya	Orissa	Gharial (male), thantia (female)
Miching	Assam	Shormon
Bengali	West Bengal	Mecho kumhir (fish-eating crocodile)
Nepali	Nepal	Chimpta (pincers), thondre, lamthora

(Whitaker *et al.* 1974, Martin and Bellairs 1977)

more than 10 m. from the water without digging any trial nests. Activity continued for 21 nights till the night of 11 April, with the exception of the night of 31 March and 3 April. In this period 28 nest holes were dug with 7 holes being the maximum number in one night. In contrast to the protracted nesting activity of these sites a solitary nesting female using a site in a nesting area different from all other areas mentioned above deposited her eggs after a single night's nesting activity on the night of 5 April in which she dug only one other nest hole apart from the hole in which she deposited her eggs.

Singh and Bustard (1977) describe a nest of 25 eggs on Satkoshia Gorge being 5.9 m from the water's edge and 2.6 m above water level. The first eggs were 37.5 cm below the surface and the bottom of the nest hole measured 30 x 22.5 cm. In 23 nests on the Chambal and Girwa, the depth of sand covering the eggs averaged 29.03 cm. Depth of the nest hole averaged 48.89 cm and diameter 52.90.

The banks of the Chambal River can be broadly classified into the following types: 1) steep sand banks 2) flat sand banks 2) steep mud banks 4) flat mud banks 5) rocky banks.

While nest hole excavation would be possible for gharial in bank types 1, 2 and 3 nesting was confined to river bank type 1) Alluvial deposits on a midriver rocky island were also used for nesting each season between 1976 and 1980. Between 1975 and 1980 all located gharial nests on the Girwa River in the Katerniaghat Sanctuary were found on a 3 km stretch of bank adjoining the highest land in the sanctuary. The same approximate sites are used each season but there are considerable alterations to the bank each year due to erosion and deposition during the monsoon high water. The Katerniaghat nest sites are therefore almost exclusively sandy subsoil exposed by erosion. Table 5 gives distances from and heights above water for 32 nests at 3 sites. Tables 6 and 7 give clutch sizes and female relatedness. Twelve nesting female gharial on the Chambal measured 3.16 m to 4.54 m (using the method described by Singh and Bustard 1977) with an average of 3.77 m; clutch sizes of these females has ranged from 10 to 64 eggs with an average of 42.

**Incubation:**

Observations on captive animals indicate an average egg development period of about

TABLE 4

DISPERSAL OF RELEASED JUVENILE GHARIAL (1979)

Locality	No.	Dispersal in one month	Dispersal in two months	Post monsoon dispersal
Chambal River, U.P.	15	200-500 m	< ½ km	< 5 km
Girwa River, U.P. (Bustard 1979, Choudhury 1979)	14	minimal	—	1-2 km

TABLE 5

NEST SITUATION

	Nests	Distance from water (m)	Height above water (m)
A. Chambal	28	4.6-14.5:9.5	1.5-3.5:2.4
B. Girwa	3	2.5- 4.0:3.2	1.0-3.0:2.0
C. Mahanadi (Singh & Bustard 1977)	1	5.9	2.5

TABLE 6

CLUTCH SIZE OF GHARIAL NESTS

Year	Place	Nests (N)	Clutch size (x)
1976	Girwa R., Chambal R.	10	45.8
1977	Girwa R., Chambal R.	18	39.5
1978	Girwa R., Chambal R.	16	39.2
1978	Rapti/Narayani R. (Nepal)	10	30.8
1979	Girwa R., Chambal R.	15	40.1
1980	Girwa R., Chambal R.	11	40.0

Number of eggs in 80 clutches = 3147;  $\bar{x}$  = 39.3:18-95 (V. B. Singh 1979, Kimura 1978)

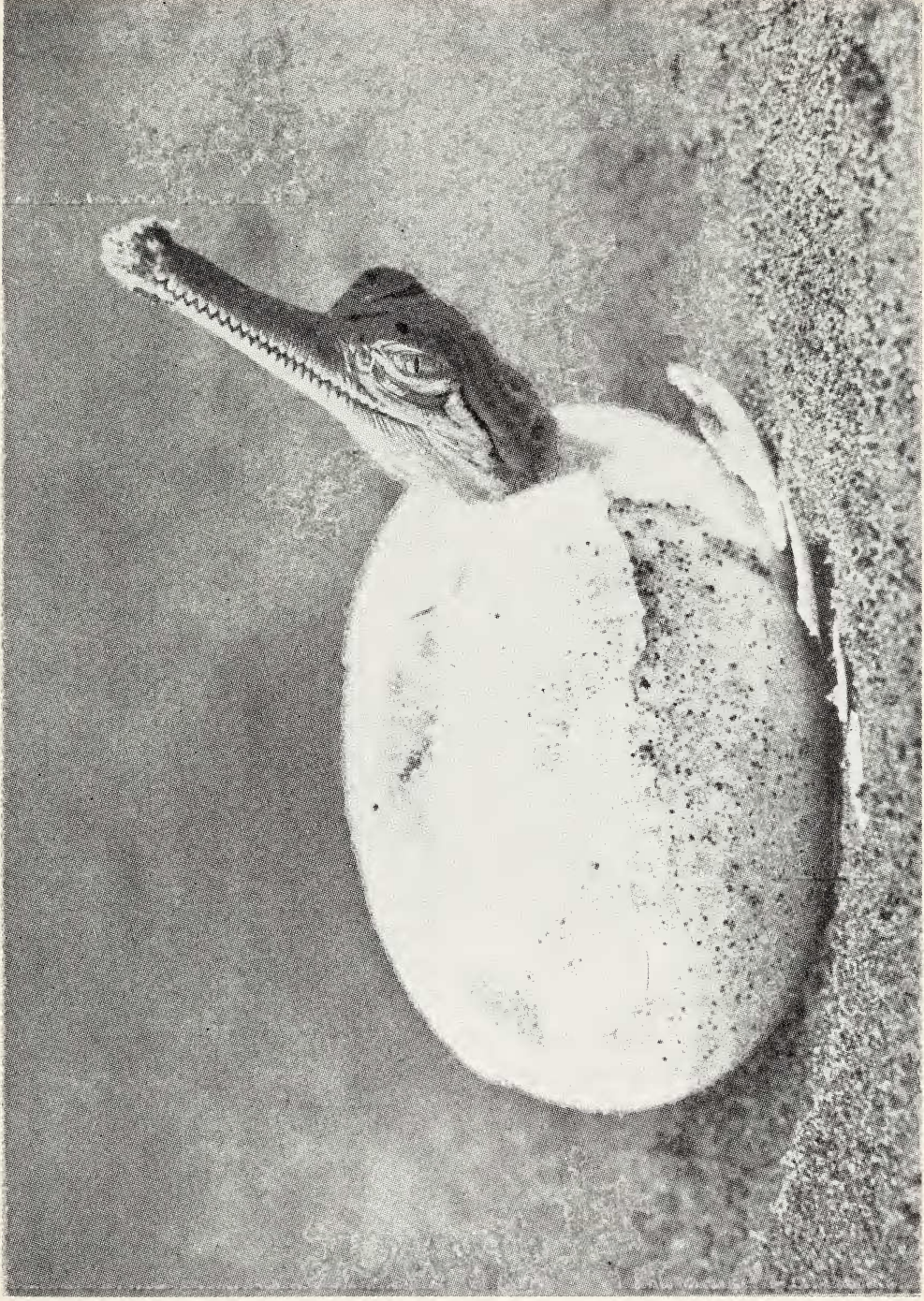
30-40 days as courtship was seen in first week February and eggs were laid on March 10th. Incubation periods in collected clutches from Nepal, Bihar and Orissa ranged from 71 to 93 days. In 1976 nests took 76 to 92 days to

hatch, an average of 84.5 (Singh and Bustard 1977). Nests on the Chambal took an average of 60-65 days to hatch pointing to the tendency for captive incubation to be done at a lower temperature. The implications of temperature for determining the sex ratio of a clutch could however be very important. Collected clutches were incubated at an average temperature of 30°C. Singh and Bustard (pers. comm.) give a temperature range of 25 to 37°C for wild nests with a humidity (sand moisture content by weight) of 4% to 7%. Nests on the Chambal had temperatures at the top of the egg mass ranging from 22°C (in April) to 36.5°C (in May). Six nests monitored for 5 days in May had an average temperature of 34.9°C.

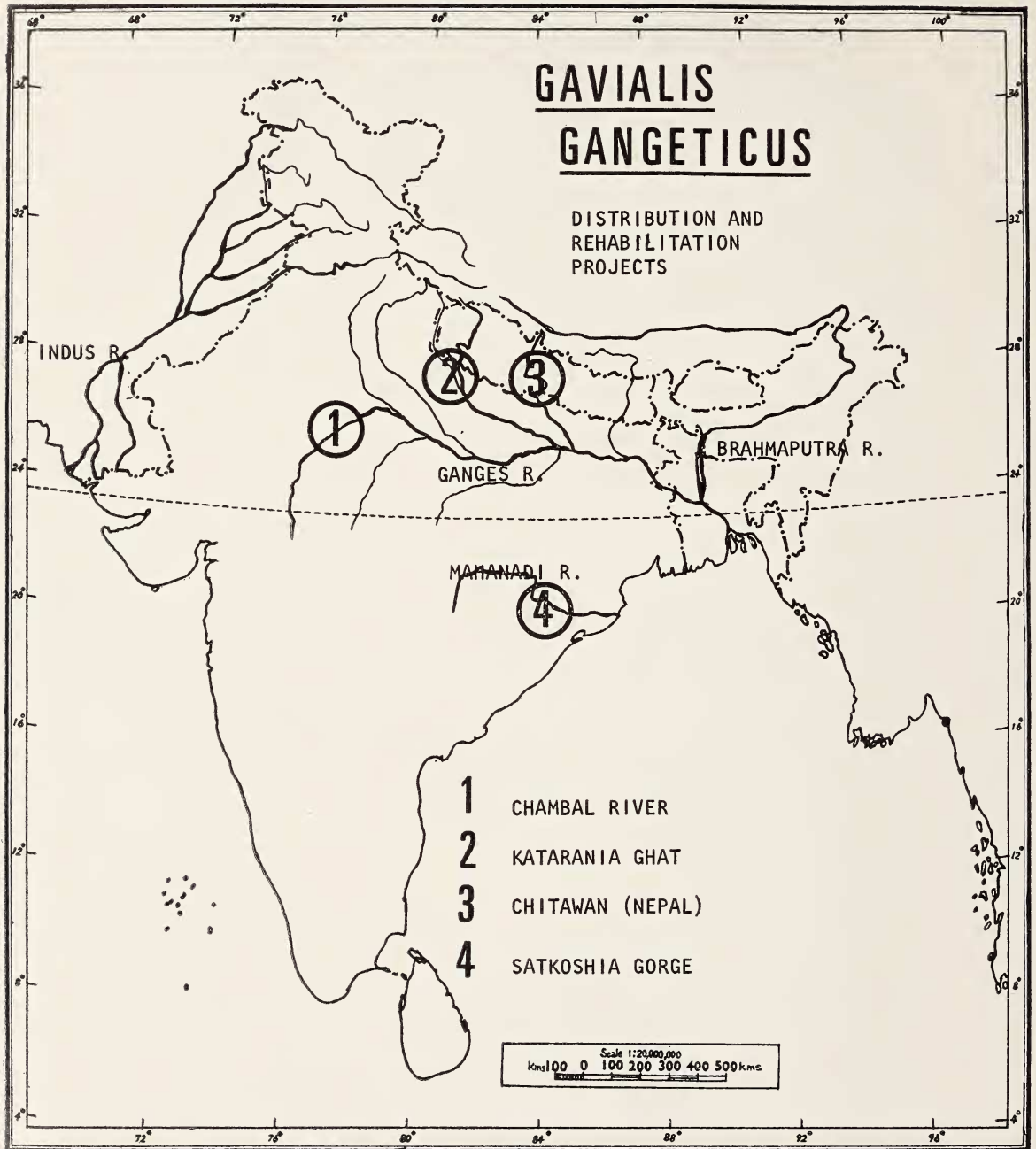
**Breeding success:**

Little is known about breeding success in the wild. The disturbed and altered status of gharial habitat may affect breeding success. For example Singh (pers. comm.) reports an infertile nest at Satkoshia Gorge where boat traffic is frequent enough that it may inhibit contact and mating.

All 70 nests found on the Chambal and Girwa Rivers between 1975-1980 were fertile. Bustard (in litt.) reported that 2.7% of eggs were damaged during laying in nests on the Narayani River in Nepal. 4.4% of the eggs in 12 nests collected in 1977 on the Girwa and Chambal Rivers were decomposed. In one nest only 5 hatchlings emerged from 49 eggs. The remainder died due to suffocation of the embryos when dune formation covered the site with 2 m of sand. One nest excavated naturally by the female was found to contain 45 hatched eggs, indicating 100% success. Most nests collected on the Girwa River have yielded hatchlings with congenital defects such as bent necks. These defects occur in up to 25%



Gharial hatchling.  
(Photo: *Rajesh Bedi*)



Map of the Indian subcontinent showing the four main river systems of gharial distribution and location of the four rehabilitation projects.

TABLE 7

## CLUTCH SIZE AND LENGTH OF FEMALE GHARIAL

Clutch size	Total length of female (cm)
15	270
30	300
41	330-360
44	330-360
56	288
44	344

(Hornaday 1885, Parshad 1914, Basu, pers. obs.)

TABLE 8

## HATCHING SUCCESS OF COLLECTED GHARIAL EGGS IN UTTAR PRADESH

Year	Nests (N)	Eggs (N)	Hatchlings (N)	% success
1975	1	38	21	55.3
1976	10	458	364	79.5
1977	18	712	632	88.8
1978	16	627	432	68.9
1979	15	602	492	81.7
1980	11	440	373	84.8

(Singh 1979, Basu, pers. comm.)

of hatchlings in affected clutches and are surmised to be of genetic origin.

In Uttar Pradesh gharial eggs are generally left in the natural nest for over half the incubation period and then shifted to the hatchery by Forest Department personnel. Table 8 illustrates the high hatching success obtained (V. B. Singh 1979).

**Hatching and post-hatching:**

Singh and Bustard (1977) report the only incident of 'remnant' nest guarding behaviour. During May, 1976 at Kakaraghat, Narayani River, Nepal, a party of 12 persons approached a nest site. The female was basking at the site and entered the water on arrival of the

team. While the eggs were collected she surfaced and remained close to the site.

On 8/4/75 a nest was laid in Satkoshia Gorge. The female visited the site 11 times in the following 77 days; the last three visits being on the 71st, 76th and 77th days, corresponding to possible hatching days (Singh and Bustard 1977). Hatching is in June, during the monsoon, with flood water and medium temperatures.

Singh and Bustard (1977) write that head morphology (sharp teeth, location of eyes, long snout and no space in mouth) preclude gharial from carrying hatchlings from the nest. Subsequently Basu and Bustard (in press) report evidence that gharial do excavate and carry their young to the water. It is possible that they carry eggs, as has also been reported in other crocodylians, but this has as yet to be observed or determined. It should be noted that the large gullet of an adult has ample room for hatchlings once in the back of the mouth.

Creche formation and protection of young has been reported by Singh and Bustard (1977). The authors record that in mid-July, 1974 an approximately 450 cm female gharial was seen in the shallows of a nullah off the Chambal River, Rajasthan. 34 hatchlings of about 375-400 mm were around and on her, some lying on her head and others on the nearby bank. Lang (pers. comm.) reports that the captive adult female at MCB responded to an imitation of a hatchling call by close approach and assuming a head-emergent at jawline posture. On July 14, 1979, 40 days post-hatching, a female was observed in the water below the nest site accompanied by 38 hatchlings. It is speculated that the creche lasts till the first rise of the river to flood level, which generally occurs by the end of July.

Captive breeding of gharial was achieved

for the first time at Nandankanan Park, Orissa, in 1980. A 4 m male gharial on loan from the Frankfurt Zoo killed the 2.8 m resident male and in early 1980 mated with one of the two females. She laid 25 eggs on March 10th, all of which reportedly hatched 58 days later on May 7th.

### Conservation:

Since 1975 intensive efforts to rehabilitate the seriously endangered gharial have met with considerable success. Under the consultancy of H. R. Bustard (FAO/UNDP), Forest Departments in the states of Orissa, Uttar Pradesh, Rajasthan and Bihar have evolved rehabilitation schemes. An estimated 100 wild gharial survived in India in 1975, half of the estimated world population. Collection of eggs and rearing the young at four main centres (Tikerpada in Orissa, Kukrail in Uttar Pradesh, Katerniaghat in Uttar Pradesh and Hyderabad in Andhra Pradesh) have so far resulted in a total of over 2000 hatchlings.

Riverine sanctuaries have been gazetted at Satkoshia Gorge (Orissa), Chambal River (Rajasthan, Uttar Pradesh, Madhya Pradesh), Katerniaghat (Uttar Pradesh) and Gandak River (Bihar) specifically for gharial rehabilitation. So far 107, 2-3 year old have been released in the Satkoshia Gorge Sanctuary, 75 in the Chambal National Gharial Sanctuary

and 14 in the Katerniaghat Sanctuary. Studies on gharial biology are the subjects of four Ph.D. scholars and students on the fisheries and riverine ecosystems are planned to support the gharial programme (Basu and Singh, pers. comm.)

Captive breeding has occurred at Nandankanan Biological Park, Orissa and is being attempted at the Madras Crocodile Bank, Tamil Nadu.

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